COVID-19 IMPACT MONITORING FOR CLIMATE ENVIRONMENT (GREENHOUSE GASES)

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ABSTRACT

To track atmospheric CO_2 changes resulting from the lockdowns, observations collected by the NASA Orbiting Carbon Observatory-2 (OCO-2) satellite and Japan's Greenhouse gases Observing SATellite (GOSAT) in 2020 were compared to results collected in previous years. The OCO-2 results were used to search for changes on regional scales over the globe. Targeted observations from GOSAT were used to track changes in large urban areas, such as Beijing and Tokyo. Both types of observations yielded key insights into the CO_2 changes accompanying the economic disruptions caused by the COVID-19 lockdowns. ESA, NASA and JAXA developed the dashboard jointly to monitor the climate impacts of COVID-19.

Index Terms—greenhouse gases, COVID-19, GOSAT, OCO-2

1. GREENHOUSE GASES OBSERVATION FROM SPACE

The Japan's Greenhouse gases observing satellite (GOSAT) and NASA'2 Orbital Carbon Observatory-2 (OCO-2) have been returning spatially resolved global estimates of carbon dioxide (CO_2) from space using different observation strategies [1, 2]. The Thermal And Near infrared Sensor for carbon Observation Fourier Transform Spectrometer (TANSO-FTS) onboard GOSAT has wide spectral coverage, extending from short wave infrared (SWIR) to thermal infrared (TIR), returning independent CO_2 estimates in the lower and upper troposphere. It also has an agile pointing system allowing it to target large urban centers. The imaging grating spectrometers onboard OCO-2 collect observations of SWIR CO_2 bands with higher spatial resolution and precision, allowing it track regional changes in CO_2.

2. TRACKING ATMOSPHERIC CO_2 CHANGES DUE TO THE COVID-19 LOCKDOWN

Lockdowns in response to the COVID-19 pandemic have led to temporary reductions in CO_2 emissions from fossil fuel combustion for transportation, industry and other human activities [3]. While these emission reductions were quite large in some areas, they were temporary. Time-dependent, regional-scale changes in CO_2 concentrations are expected to be no larger than 1 part per million (ppm), out of the normal 415 ppm CO_2 background – a change of only 0.25%. Here, our objective was to determine whether these small changed could be detected by the current generation of space-based CO_2 monitoring satellites. Determining whether these temporary reductions in CO_2 emission are significant enough to contribute to the overall lowering of the world's carbon footprint will require more time and rigorous scientific study.

3. REGIONAL SCALE CHANGES IN CO_2 ACROSS THE GLOBE

OCO-2 observations are analyzed to estimate the column-averaged dry-air mole-fractions of CO_2 (XCO_2) for more than 85,000 cloud-free observation points each day. OCO-2 XCO_2 estimates collected in 2020 were assimilated into the Goddard Earth Observing System (GEOS) Constituent Data Assimilation System (CoDAS), along with estimates of atmospheric transport, to produce daily, regional-scale global maps of CO_2. These maps were compared to GEOS maps generated using CO_2 emissions estimated from 2015-2019 to identify changes due to the COVID-19 lockdowns. These comparisons revealed CO_2 reductions whose timing and spatial distribution were well correlated with the CO_2 emission changes estimated from fossil fuel use statistics from the Global Carbon Project during the peak periods of the lockdowns in early 2020.

Figure 1 shows differences between the 2020 CO_2 fields and those anticipated using emissions from the 2015-2019 baseline for the peak periods of the lockdowns in China (early February), southern Europe (early April) and the eastern U.S. (late April). The results show small (about 0.2 to 0.5 ppm, or

0.05-0.125%) reductions in CO_2 over each region at times that are well aligned with the largest CO_2 emissions reductions reported by the Global Carbon Project. The CO_2 map for late April also appears to show a partial recovery in CO_2 levels over East Asia and northern Pacific Ocean, as China began to emerge from its initial coronavirus lockdowns. The maps also reveal many features that are not likely to be associated with the lockdowns. The enhanced CO_2 values in the southern hemisphere are most likely due in part to the large wildfires over Australia in late December 2019, while the enhanced values in central Asia in April include contributions from wildfires in Siberia.

The reduced CO_2 over India and East Africa early in 2020 was most likely due to enhanced CO_2 uptake by the land biosphere, due to heavy rains there in late 2019. These results show that an accurate assessment of changes in fluxes from the natural carbon cycle is needed to attribute changes anthropogenic emissions.

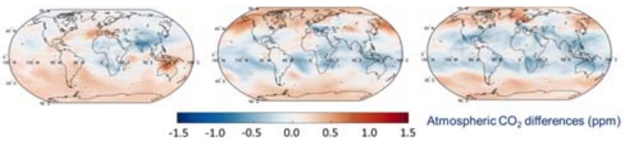


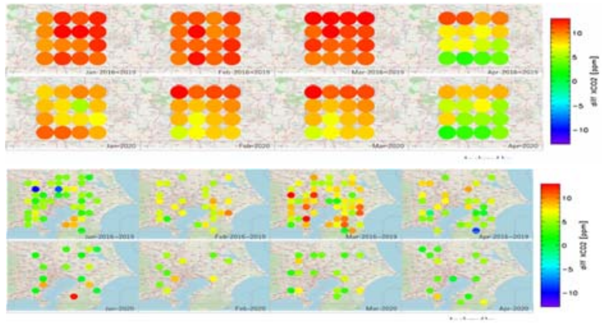
Figure 1. Differences in CO_2 distributions derived using OCO-2 observations in 2020 and those estimated using background CO_2 emissions from 2015-2019. 16-day averages are shown for mid-February (left), early April (middle) and late April (right), when lockdowns were imposed in China, Europe, and the U.S.

4. CO_2 CHANGES OVER LARGE URBAN AREAS

While OCO-2 is optimized for detecting the subtle, regional-scale changes in CO_2, GOSAT has advantages for tracking changes in CO_2 emissions over large cities. With its 2-axis pointing system, TANSO-FTS can routinely collect measurements of atmospheric CO_2 over large urban areas, which experienced the largest changes in economic activity associated with the onset of the COVID-19 pandemic. Its FTS multiplex advantage allows it to simultaneously measure reflected SWIR sunlight with two linear polarizations as well as thermal emission from Earth's surface and atmosphere at high spectral resolution. TANSO-FTS spectra collected over this wide range are analyzed to reduce errors caused by aerosol scattering and provides partial column densities of CO_2 from the lower (0-4 km) and upper (4-12 km) troposphere, XCO_2(LT) and XCO_2(UT), respectively.

Here, we assume that CO_2 emissions from fossil fuel use and other sources contribute to higher XCO_2(LT) vales over cities, relative to XCO_2(UT), which are less affected by city emissions and can be adopted as background values. Difference between XCO_2(LT) and XCO_2(UT) therefore track changes in city emissions.

Figure 2 shows monthly-averaged distribution of XCO_2(LT)-XCO_2 $(UT)_{area\text{-}average}$ over Beijing, China and Tokyo, Japan, derived from GOSAT observations collected in January through April of each year from 2016 to 2020. The results from earlier years illustrate the amount of month-to-month variability in the observed CO_2 enhancements that is typical during this season. However, while the CO_2 concentration enhancements vary substantially from month-to-month, they are generally much lower in 2020 than in earlier years.

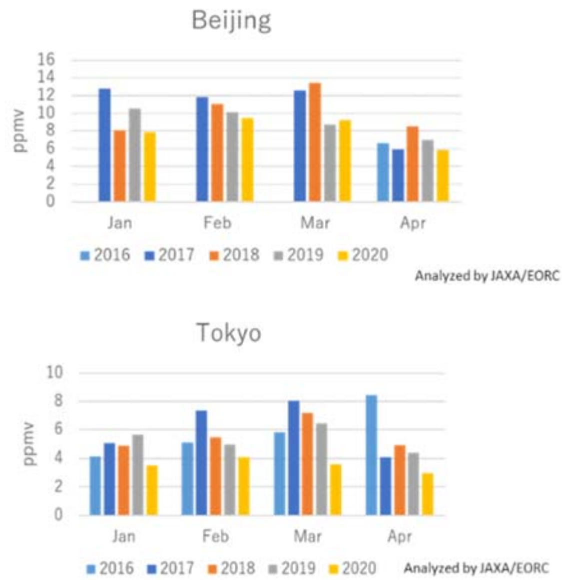


(a)

(b)

Figure 2. Monthly average of XCO_2(LT)-XCO_2 $(UT)_{area\text{-}average}$ at targeted footprints in the upper and lower troposphere in January, February, March, and April in 2020 compared to 2016-2019 in (a) Beijing and (b) Tokyo.

Figure 3 (a) shows monthly time series of area-averaged XCO_2(LT)-XCO_2 (UT) over Beijing. For Beijing all months in 2020 have smaller CO_2 enhancements relative to prior years. While this behavior is consistent with reported COVID-19-related reductions in fossil fuel emissions from Beijing, they also include contributions from other processes such as passing weather systems. Similar results were derived for the other cities such as Tokyo as shown in Figure 3 (b).



(a)

(b)

Figure 3. Monthly and area-averaged XCO_2(LT)-XCO_2 (UT): (a) Beijing and (b) Tokyo.

5. EARTH OBSERVING DASHBOARD

Other urban areas including in the Southern hemisphere have been monitored. CO_2 enhancements are analyzed and updated continuously, and results can be accessed at the NASA-ESA-JAXA tri-agency dashboard (https://eodashboard.org/), the NASA COVID19 dashboard (https://earthdata.nasa.gov/covid19/), and the JAXA for Earth on COVID-19 (http://earth.jaxa.jp/covid19/en/).

6. WAY FORWARD

NASA, JAXA and ESA have extended the COVID-19 Dashboard effort through at least the end of 2021. Regular updates will be delivered as they become available to track the evolution of the COVID-19 pandemic. These results will extend the timeline and include more megacities.

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